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(54) **A precalciner rotary kiln system for cement manufacture**

(57) A precalciner rotary kiln system (1) for cement manufacture. According to the invention there is provided an oxygen source (20) connected to the hot air duct (16) leading to the precalciner (10) of the precalciner rotary kiln system through a dosage unit comprising an endless header pipe (22) provided around the hot air

duct and connected to the oxygen source through an oxygen inlet line (23) and a plurality of nozzles (25) connected to the header pipe and protruding into the hot air duct. The nozzles are staggered along the hot air duct and tilted in the direction of flow of hot air through the hot air duct (Figs 1 and 2).

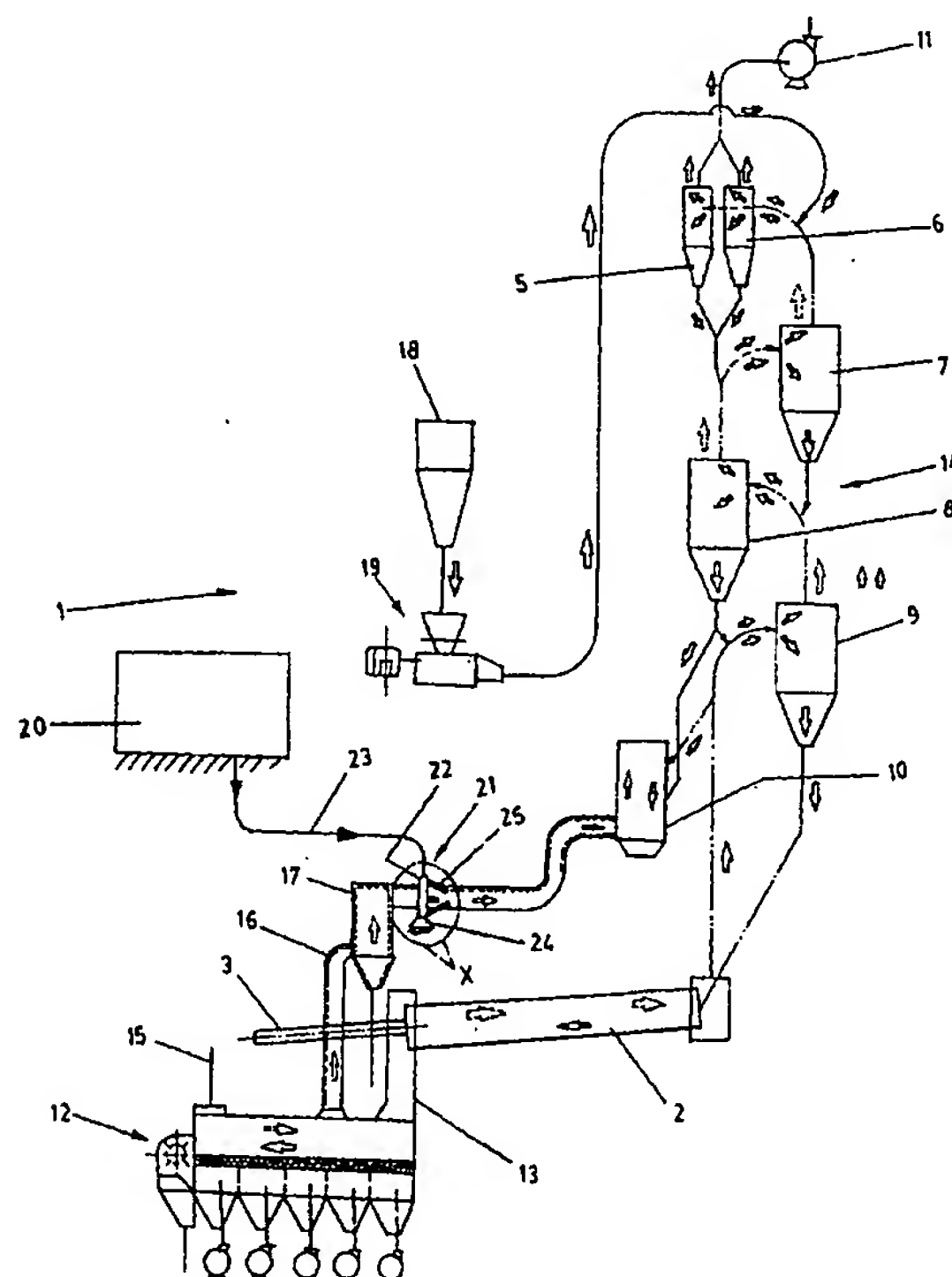


FIG 1

EP 1 235 044 A1

**Description****FIELD OF THE INVENTION**

5   **[0001]** This invention relates to a precalciner rotary kiln system for cement manufacture.

**PRIOR ART**

10   **[0002]** An increase in temperature in the sintering zone of a rotary kiln may be obtained by use of oxygen enriched air preferably along with preheated combustion air. Increase in flame temperature results in increased heat transfer by radiation in the sintering zone of a cement rotary kiln. According to Stefan-Boltzmann Law (cf "Efficient Use of Fuel" publication, His Majesty's Stationery Office (HMSO), London) the rate of heat transmission by radiation varies as the fourth power of the absolute temperature. Therefore, the higher the temperature difference between the hotter and cooler surfaces in the sintering zone of a rotary kiln, the greater is the heat transfer by radiation. Literature references

15   pertaining to use of oxygen enriched air in the sintering zone of a rotary kiln discuss pilot scale tests or short duration trials in larger capacity operating cement rotary kilns by dry or wet process route. These pilot scale trials are concerned with introduction of oxygen enriched air and fuel component through the kiln firing pipe into the sintering zone of a cement rotary kiln to increase the flame temperature and to obtain improved fuel efficiency and higher kiln outputs.

20   **[0003]** K D Foalle ("World Cement", December 1984) reviews earlier studies on use of oxygen in rotary cement kilns and gives data on a wet process coal fired rotary kiln, where oxygen enriched air was used on a plant trial basis. He indicates a 20% increase in productive capacity and 5% reduction in fuel consumption of 1580 kcals/kg clinker. The data presented by Foalle would not be relevant to present day precalciner rotary kiln systems having fuel consumption below 750 kcal/kg clinker and clinker productivity of 10,000 tpd (tons per day) for single stream operating units. In such systems 35 to 40% of total fuel is used in the kiln system, while the balance 65-60% fuel is fed to the precalciner. The

25   primary air introduced through the firing pipe into the kiln constitutes only 10% of the combustion air requirement of the kiln (exclusive of the precalciner). The scope for incorporation of oxygen through the kiln firing pipe would therefore be very restricted. The path length of combustion air entering the kiln through the grate cooler at around 900°C is relatively short. This involves a steep gradient in temperature of the combustion air in the cooler transition zone. Introduction of oxygen in the kiln through this zone would involve difficulties in precise dosage control. When introducing

30   oxygen by a separate pipe through the firing pipe along with fuel, close control over flame shape and intensity is essential for maintaining a satisfactory protective clinker coating in the sintering zone to prolong refractory life in the sintering zone. This is very difficult to achieve. Also, dusty conditions in the sintering zone affect flame visibility, particularly when coal is used as a fuel. Therefore precise measurement of sintering zone temperature by infrared or optical pyrometer is difficult. Dosage of oxygen through the kiln firing pipe may have to be restricted to below 28%

35   oxygen content in the oxygen-air stream. This would greatly curtail the amount of oxygen that may be incorporated in a precalciner-rotary kiln system.

**OBJECTS OF THE INVENTION**

40   **[0004]** An object of the invention is to provide a precalciner-rotary kiln system for cement manufacture which achieves accelerated combustion and increased production by introduction of oxygen in the precalciner (secondary furnace) where heat transfer is effected to raw material particles that are suspended in the hot gases.

45   **[0005]** Another object of the invention is to provide a precalciner rotary kiln system for cement manufacture which reduces power consumption of precalciner-cyclone preheater system by reducing the exit gas quantity leaving the precalciner-kiln system.

**[0006]** Another object of the invention is to provide a precalciner rotary kiln system for cement manufacture which is smooth and steady in operation.

50   **[0007]** Another object of the invention is to provide a precalciner rotary kiln system for cement manufacture which utilises surplus quantity of lower temperature air from the grate cooler (or other source) for instance to preheat cement raw meal.

**DESCRIPTION OF THE INVENTION**

55   **[0008]** According to the invention there is provided a precalciner rotary kiln system for cement manufacture consisting of an oxygen source connected to the hot air duct leading to the precalciner of the precalciner rotary kiln system through a dosage unit.

**[0009]** The following is a detailed description of a preferred embodiment of the invention with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram of a precalciner rotary kiln system for cement manufacture according to an embodiment of the invention;

Fig 2 is enlarged cross section of the portion marked by X in Fig 1; and

Fig 3 is a section at Y-Y in Fig 2.

**[0010]** In Fig 1 the arrows in continuous lines indicate material flow and the arrows in dotted lines indicate gas flow.

**[0011]** Referring to Figs 1 to 3 of the accompanying drawings, 1 is a precalciner rotary kiln system consisting of a rotary kiln 2 whose firing pipe is marked 3. The rotary kiln is fed by a four stage suspension cyclone preheater system 4 comprising a first stage of two cyclone preheaters 5 and 6 in parallel, a second stage of cyclone preheater 7, a third stage of cyclone preheater 8, a fourth stage of cyclone preheater 9 and a precalciner 10 connected to the cyclone preheaters 8 and 9. 11 is an induced draft fan connected to the cyclone preheaters 5 and 6. 12 is a grate cooler connected to the rotary kiln through a throat 13. 15 is a low temperature hot air duct vent. 16 is a hot air duct from the grate cooler to the precalciner. 17 is a cyclone dust collector provided with the hot air duct. 18 is a raw meal feed silo. 19 is the continuous pneumatic conveyor system feeding raw meal to the cyclone preheater system.

**[0012]** There is provided an oxygen source 20 connected to the hot air duct through a dosage unit 21 between the dust collector and the precalciner. The dosage unit comprises an endless header pipe 22 provided around the hot air duct and connected to the oxygen source through an oxygen inlet line 23. 24 is a support for the header pipe. A plurality of nozzles 25 is connected to the header pipe and protrude into the hot air duct. The nozzles are staggered along the hot air duct tilted in the direction of flow of hot air through the hot air duct. Oxygen enters the hot air duct through the nozzles and mixes with hot air therein. Dust in the hot air passing through the hot air duct is trapped in the cyclone dust collector. Residual dust entry into the nozzles is minimised by the tilted positioning of the nozzles in the direction of flow of the hot air. The staggered positioning of the nozzles along the duct ensures better mixing of oxygen and hot air prior to entry into the precalciner.

**[0013]** The multistage suspension cyclone preheater system may be of a different configuration such as five or six stages or two or more strings of multi stage systems in parallel configuration with the precalciner connected to one string while the other strings handle kiln exit gases.

**[0014]** The temperature in the precalciner is required to be maintained below 900°C for achieving 90 to 95% decarbonation of cement raw meal in the precalciner prior to entry into the kiln. Around 60 to 65% of total fuel to the kiln-precalciner system is fed to the precalciner. By supply of oxygen enriched preheated combustion air to the precalciner, increased and accelerated combustion is achieved, along with a reduction in residence time and higher throughput for the precalciner, particularly when coal is used as a fuel. This is because of the favourably higher oxygen content and reduced volume of the incoming preheated combustion air which has a lower nitrogen content. Correspondingly, there is a reduction in volume leaving the precalciner and cyclone preheaters. Thus, fuel consumption is reduced, because of lesser waste heat loss in exit gases. By targetting to maintain precalciner combustion temperature at a lower level of say 850°C, further fuel saving can be achieved on account of lower heat loss in exit gases. There is a further saving in power consumption for preheater waste gas fan due to reduced volume of exit gases because of lower nitrogen content in combustion air to the precalciner. Reduction in gas volume flow (Nm<sup>3</sup>/kg clinker) through the precalciner and cyclone preheaters enables utilisation of reserve design flow capacities for increasing the productive capacities of the system. Optionally the reserve waste gas fan capacity would be available for higher production. Reduced exit gas volume of the precalciner per kg clinker ensures smooth and steady operation at a higher clinker production. Optimum economy can be effected by use of 90% oxygen, for which capital and power cost is lower. Introduction of oxygen into the precalciner is simple and far more precise as compared to introduction of oxygen into the kiln through the fuel firing pipe or by incorporation into the secondary stream from the cooler to the kiln. This is because of the lower combustion temperature in the precalciner (below 900°C), and a far more precise dosage control of oxygen. By incorporation of oxygen in the precalciner, overall fuel savings for the kiln and precalciner enable a reduction in total combustion air requirements from the grate cooler for both the kiln and precalciner. Even when oxygen enriched air is supplied specifically to the precalciner, the benefit of an enhanced combustion air temperature from the grate cooler is available for both the kiln and precalciner. A further overall fuel saving is thus effected. There is a greater flexibility in choice of fuel because of better ignitability of fuel in the precalciner due to use of oxygen enriched combustion air. As an example lower volatile matter sub bitumenous coal can be used. Use of oxygen enriched combustion air in the precalciner is eco-friendly since no pollution is involved in the manufacture of oxygen. Also, there is a reduction in consumption of fossil fuel per kg clinker. Further, the lower temperature of combustion in the precalciner enables a reduction of NO<sub>x</sub> emission in the vented exit gas. Incorporation of oxygen in combustion air for the precalciner will be specially relevant to present generation precalciner-kiln systems with fuel efficiencies below say 700 kcals/kg clinker. Thus, as a result of incorporating say 0.04 Nm<sup>3</sup> of oxygen per kg clinker in the preheated combustion air for precalciner, fuel consumption is reduced from 730 kcals/kg clinker to around 700 kcals/kg clinker. Corresponding oxygen content

by volume for combustion air expressed as a total for kiln-precalciner system will be 25%. The oxygen content will be significantly lower than 25% for an earlier generation precalciner-kiln system with fuel efficiency of say 830 kcals/kg clinker. By incorporation of oxygen in the combustion air for the precalciner, there is an increased surplus quantity of lower temperature air to be vented from the grate cooler. This heat can be advantageously utilised for additional enhancement of precalciner-rotary kiln productivity and fuel efficiency, particularly where troughed grate plates are being used. A potential additional fuel saving of 50 kcals/kg clinker and an additional potential clinker production of 25% can be achieved.

[0015] The following comparative Table 1 gives a summarised indication of fuel efficiency, productive capability and other parameters for a precalciner-rotary kiln system with fuel consumption of 730 kcals/kg clinker with and without oxygen incorporation. Data relating to the precalciner-rotary kiln system with oxygen incorporation are based on fuel distribution ratio of 40:60. Data relating to the precalciner rotary kiln system without oxygen incorporation are based on established norms given in manufacturers' technical presentations and other literature sources.

TABLE I

	Without oxygen enrich- ment			With 0.04 Nm <sup>3</sup> of oxygen per kg clinker incorpor- ated with combust- ion air to precalciner		
	Kiln	Pre- calciner	Total	Kiln	Pre- calciner	Total
1a) Fuel cons- umption(net kcal/kg clinker) based on 40:60 kiln/ precalciner fuel ratio	292 + 438	730		292 + 438 - 27	- 27	730
	292	411	703			
1b) Raw material/ clinker ratio		1.5			1.5	
2a) Correspond- ing combus- tion air re- quirement (Nm <sup>3</sup> /kg clinker)						
N <sub>2</sub>	0.286	0.429	0.715	0.286	0.278	0.564
O <sub>2</sub> incor-	-	-	-	-	0.04	0.04
O <sub>2</sub> porated	0.076	0.114	0.190	0.074	0.074	0.15
from air	0.362	0.543	0.905	0.362	0.392	0.754
As per Duda's Handbook, 1000 kcal calorific value of bitumenous coal has an equivalent combustion air/combustion gas volume of 1.24 Nm <sup>3</sup> . As an example $\frac{242}{1000} \times 1.24 = 0.362$						
2b) %Oxygen by volume	21	21	21	21	29	25
3) Temperature of combustion air °C	950	750		950	800	

	Without oxygen enrichment			With 0.04 Nm <sup>3</sup> of oxygen per kg clinker incorporated with combustion air to precalciner		
	Kiln	Pre- calciner	Total	Kiln	Pre- calciner	Total
4) Heat recouped from grate cooler(kcals/kg clinker)		0.362 x 1.293 x				
Density of air		0.24 (950 - 50)				
1.293 = 101		118	219	101	97	198
Sp heat of air 0.24						
5) Exit gas volume vented from pre- heater Nm <sup>3</sup> /kg clinker		1.4		(1.4 - (0.905 - 0.754)) = 1.4 - 0.15 = 1.25		
6) Exit gas temperature °C		335		300		
7) Heat loss in exit gas (kcals/kg clinker)		1.4 x 1.316 x 0.24 x (335 - 50)				
where 1.316 is density of exit gas		= 126			99	
0.24 is sp heat of exit gas & 50°C is ambient temp						
8) Heat saved by incorporation of oxygen (kcals/kg clinker)				(126 - 99) = 27		
9) Corresponding fuel efficiency (net kcals/kg clinker)				(730 - 27) = 703		

	Without oxygen enrich- ment	With 0.04 Nm <sup>3</sup> of oxygen per kg clinker incorpor- ated with combust- ion air to precalciner
	Kiln    Pre-    Total calciner	Kiln    Pre-    Total calciner
10) % potential increase in clinker pro- duction based on reserve capacity of precalciner- preheater units		$\frac{1.4}{1.25} \times 100 = 112\%$

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[0016] In the above Table for both with and without incorporation of oxygen, kiln/precalciner distribution ratio of 40:60 has been indicated. The objective is to achieve decarbonation of 90 to 95% in the precalciner before entry of raw meal into the kiln. Based on incorporation of 0.04 Nm<sup>3</sup> of oxygen per kg clinker, fuel efficiencies without and with oxygen incorporation are 730 and 703 kcals/kg clinker respectively, ie a net saving of 27 kcals/kg clinker with oxygen incorporation. The split up combustion air composition without oxygen incorporation is 21% oxygen by volume, while that of the combustion air for the precalciner is 29% oxygen by volume. The total combustion air stream for kiln and precalciner with oxygen incorporation has a higher oxygen content of 25% by volume. Because of the corresponding lower nitrogen content, exit gas volume vented from the preheater is reduced from 1.4 Nm<sup>3</sup>/kg clinker without oxygen to 1.25 Nm<sup>3</sup>/kg clinker with oxygen incorporation, ie a reduction of 0.15 Nm<sup>3</sup>/kg clinker. This reduction in exit gas volume enables a 12% increase in clinker production capacity based on utilisation of the reserve dimension capacity of the precalciner/cyclone preheater system. The above indicated fuel saving and increase in clinker production capacity are conservatively based. For example, the volume of oxygen enriched combustion air for the precalciner is  $\frac{0.392}{0.546} \times 100 = 72\%$  of a corresponding combustion air stream without oxygen. A resultant higher precalciner combustion air temperature of over 900°C can be achieved with oxygen incorporation. However, a lower temperature of 800°C has been indicated in Table I. Also, because of a reduction in exit gas volume from 1.4 to 1.25 Nm<sup>3</sup>/kg clinker, exit gas temperature would drop to below 280°C. However, in Table I, a higher exit gas temperature of 300°C with oxygen incorporation has been indicated.

[0017] On a conservative basis a further fuel saving of 50 kcals/kg clinker and an additional potential clinker production can be achieved by utilising available surplus lower temperature hot air from the grate cooler for preheating of raw meal feed to the precalciner rotary kiln system. According to the invention oxygen of lower purity of 90% can be utilised for incorporation in the preheated combustion air requirement of the precalciner. A relatively lower dosage of upto 0.1 Nm<sup>3</sup> of oxygen per kg clinker could be incorporated in the combustion air to the precalciner corresponding to oxygen content of below 39% by volume expressed as percentage of total combustion air for the kiln and precalciner.

[0018] Instead of the hot combustion air coming from the grate cooler, it may be taken from an air/exit gas heat exchanger system located before the waste gas fan of the suspension cyclone preheater system 4. This would be relevant for a white cement plant where emerging hot clinker is commonly quenched in a water stream for obtaining a desired bluish tint.

## 55 Claims

1. A precalciner rotary kiln system for cement manufacture consisting of an oxygen source connected to the hot air duct leading to the precalciner of the precalciner rotary kiln system through a dosage unit.



2. A precalciner rotary kiln system as claimed in claim 1, wherein the dosage unit comprises an endless header pipe provided around the hot air duct and connected to the oxygen source through an oxygen inlet line and a plurality of nozzles connected to the header pipe and protruding into the hot air duct, the nozzles being staggered along the hot air duct and tilted in the direction of flow of hot air through the hot air duct.

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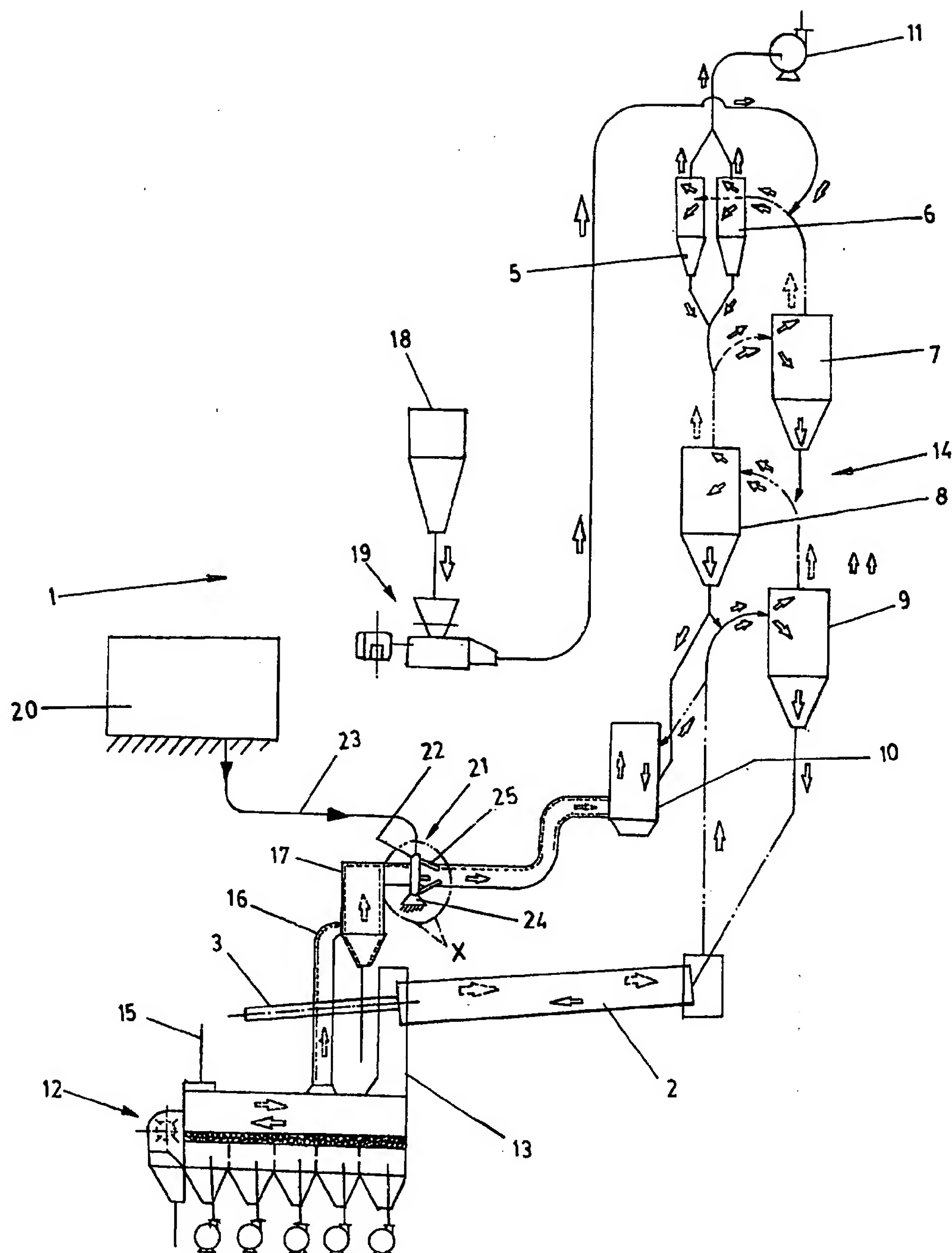


FIG 1

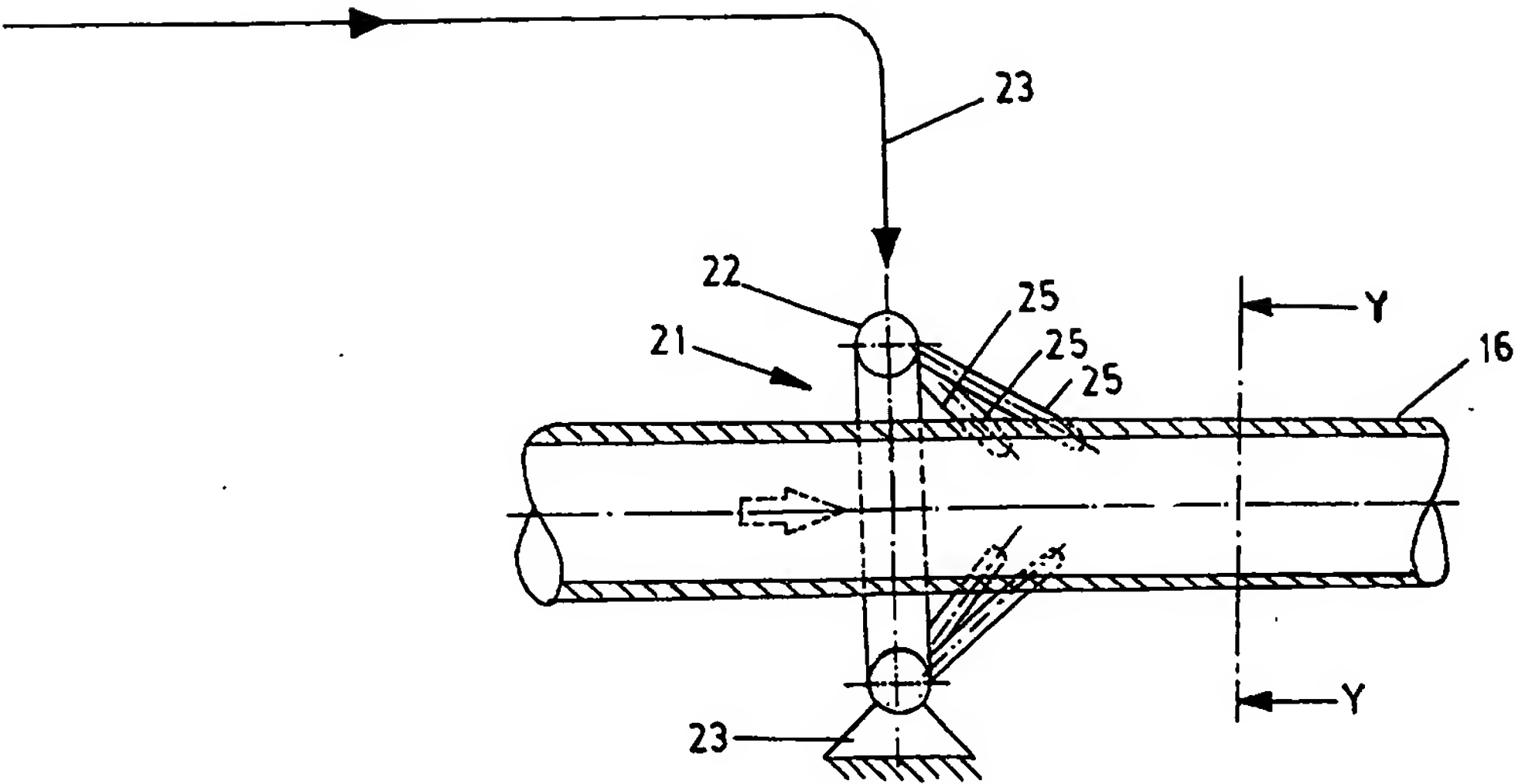


FIG 2

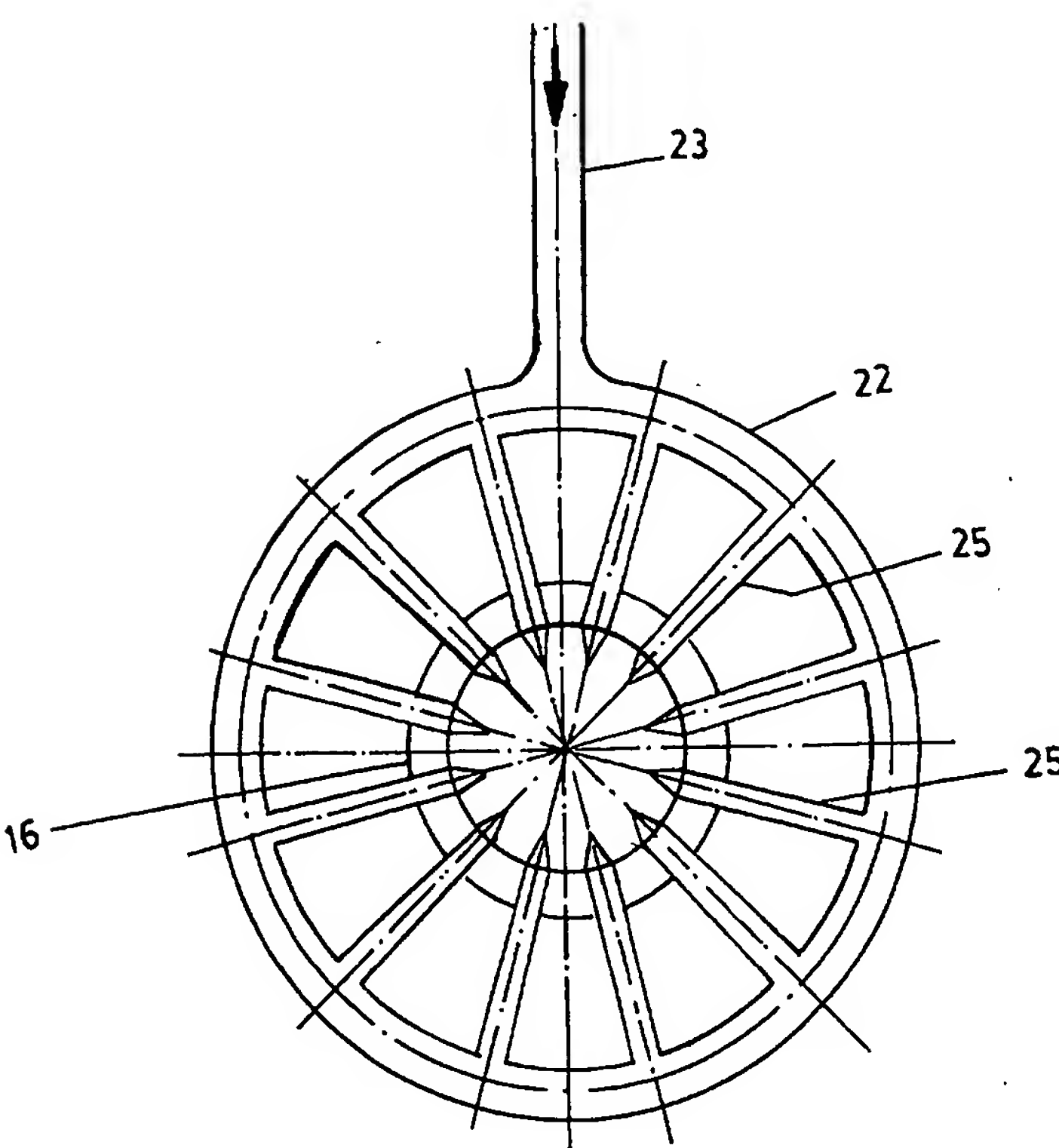


FIG 3



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# EUROPEAN SEARCH REPORT

Application Number  
EP 01 30 1541

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X	US 4 913 742 A (L.KWECH) 3 April 1990 (1990-04-03) * abstract, line 18 to 20 * * figure 1 *	1	
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A	US 4 187 071 A (K.BRACHTHÄUSER) 5 February 1980 (1980-02-05)		TECHNICAL FIELDS SEARCHED (Int.Cl.7) F27B B01F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 31 August 2001	Examiner Coulomb, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82